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THE EFFECT OF PHOSPHORUS CONTENT IN SUBSTRATE ON LEAD ACCUMULATION BY CARROT (*DAUCUS CAROTA* L.) AND LETTUCE (*LACTUCA SATIVA* L. VAR. *CAPITATA* L.)

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Summary

A pot experiment was conducted to study the effect of phosphorus treatment on lead accumulation by carrot and lettuce. It was found that raising phosphorus contents in the substrate from 50 to 800 mg kg^{-1} caused a decrease in carrot root Pb content on the average by 44% and in lettuce leaves on the average by 33%.

key words: carrot, lead, lettuce, phosphorus

INTRODUCTION

Wide implementation of the results obtained in a long-term monitoring of soil and plant heavy metal contents caused a sense of threat with these metal presence in the environment to be embedded in social awareness. Two trends have been visible while seeking the methods of preventing heavy metal penetration from soil to the food chain. Some concepts are based on the idea that these metals are removed with plant material, i.e. on phytoremediation (Cunningham & Ow 1996). However, there are still many question marks and no practically tested solutions. The other ideas focus on the procedures that cause stronger binding of heavy metals with soil components and limit their penetration to the plant root systems. Liming, organic and mineral fertilisation are among them. These procedures not only diminish heavy metal accumulation from soil by cultivated crops but also constitute a part of routine agrotechnical measures, which does not significantly increase the costs of crop cultivation in heavy metal polluted soils. Particular attention is paid to phosphate fertilisation, due to easy formation of many heavy metal insoluble phosphates in soil (Rabinowitz 1993) and to the role of phosphate ion in plant defensive strategy against these metals (Tukendorf 1990). The work aimed to test in the pot experiment conditions the effect of phosphate treatment on lead accumulation in carrot (*Daucus carota* L.) and in lettuce (*Lactuca sativa* L. var. *capitata* L.)

MATERIALS AND METHODS

The experiment was carried out in 1997-1998 on the Faculty of Horticulture Agricultural University of Cracow experimental farm with two carrot cultivars, i.e Karo F_1 and Kama F_1 and two lettuce cultivars, i.e. Syrena and Ara. The substrate composed of ground highmoor peat and washed river sand contained 8% of organic matter 20 mg Pb kg^{-1} d.w. was assayed in it, which remains within the range of this element natural soil content The substrate was fertilised with 250 mg N, 250 mg K and 60 mg Mg · kg^{-1}, and microelements. Monocalcium phosphate dosed 50, 200 and 800 mg P · kg^{-1} d.w. was used for phosphate treatment and the differences in the substrate acidity were supplemented to pH 6.5 using calcium carbonate. Lead was introduced into the substrate in 0, 275 and 550 mg per kg d w doses as lead acetate. The Mitscherlich pots, 6 per combination, were placed in the hotbeds and 8 equal carrots and 3 lettuces per pot were cultivated in the prepared substrates. The plants were watered with re-distilled water at 70% of water capacity up till their harvest maturity After the harvest the plants were thoroughly washed and lead contents were assessed in carrot roots and leaves, and in lettuce leaves The results were statistically evaluated by an analysis of variance in a fully randomised design, and differences between means were verified by Student's test at 0.05 confidence level

RESULTS AND DISCUSSION

The results of lead contents of carrot roots and leaves were given in Table 1. (Due to the lack of seasonal effect only means for two years were given.)

Lead contents in the roots of control plants were higher than permissible according to the Polish standard for root and foliar vegetables (i.e 0.50 mg kg^{-1} f.w at dry weight content 15% - 3.30 mg · kg^{-1} d w) and ranged between 3.8 and 4.4 mg · kg^{-1} d w. In the carrot leaves this metal level was much higher, i e. between 26.3 and 42.4 mg · kg^{-1} d.w Such result may be due to close localisation of the experiment to the Cracow city centre

Lead addition into the substrate containing the least of phosphorus (50 mg kg^{-1} d w.) caused a strong increase in this metal uptake by carrot. In Karo cv. roots 11.8 times and in leaves 3.3 times more lead was detected under the influence of higher Pb dose than in plants harvested from the substrate without this element addition. Comparison of lead contents in carrot grown on substrates with diversified lead contents has revealed that an average root Pb level decreased by 29% when phosphorous treatment increased from 50 to 200 mg kg^{-1} d w, and by 44% when the dose raised from 50 to 800 mg · kg^{-1} d w ; in leaves the decreases were respectively by 30% and 48%.

Kama cv. accumulated significantly less lead than Karo cv It was calculated that the relation between lead contents of leaves and roots decreased along with increasing substrate content of phosphorus The quotient for plants harvested from 50 and 800 P · kg^{-1} d.w. substrates at higher Pb dose was 2.66 and 2.38 for Karo cv and 2.14 and 1 77 for Kama cv.

Table 1. Effect of phosphate fertilisation on lead accumulation in roots and leaves of carrot Karo F_1 and Kama F_1 cvs at different lead content in substrate (mg·kg^{-1} d.w.)

P in substrate (mg kg^{-1} d.w.)		50			200			800			Means for cvs.
Pb dose (mg kg^{-1} d.w.)		0	275	550	0	275	550	0	275	550	
Karo F_1	roots	4 4ab*	46 2l	52.0m	3 8a	26.6f	42 0k	4 0a	22.5d	29.7g	25 7b
	leaves	42 4b	129 4i	138 3j	31 8a	72 6de	108 7g	26 3a	59 6c	70 6d	75 5b
	leaves/ roots	9 64	2 80	2 66	8 37	2.72	2 59	6.58	2 65	2 38	
Kama F_1	roots	4 6b	36.2i	56.3n	4 4ab	24.6e	41 3j	4.0a	20.8c	32 0h	24 9a
	leaves	29 5a	80 0ef	120 6h	26 8a	53 2c	83 4f	24 2a	44.0b	56 6c	57.6a
	leaves/ roots	6 41	2 21	2 14	6 09	2 16	2 02	6.05	2 12	1 77	
Means for P in roots		33 3c			23 8b			18 8a			
Means for Pb in roots		4 2a	29.5b	42 2c							
Means for P in leaves		90 0c			62 8b			46 9a			
Means for Pb in leaves		30.2a	73.2b	96 4c							

* Values followed by the same letter do not differ significantly

Table 2 shows the lead contents on lettuce leaves Pb levels in lettuce leaves cultivated on substrates without lead addition ranged between 9 2 and 10 6 mg kg^{-1} d w and also exceeded the standard for foliar vegetables After lead introduction into the substrate receiving the weakest phosphate treatment this element content increased triple as the effect of 550 mg Pb kg^{-1} d.w in Syrena cv and 3 2 times in Ara cv On the substrates with higher level of phosphorus Pb accumulation by lettuce was weaker An increase in phosphorus contents from 50 to 200 mg kg^{-1} d w caused an average decrease in lettuce lead by 33%, whereas further increasing its content produced only slight effect Ara cv accumulated on an average more lead than Syrena cv

Table 2. Effect of phosphate fertilisation on lead accumulation in leaves of lettuce Syrena and Ara cvs. at different lead content in substrate (mg kg^{-1} d w)

P in substrate (mg kg^{-1} d w)		50			200			800			Means for cvs.
Pb dose (mg kg^{-1} d.w.)		0	275	550	0	275	550	0	275	550	
Syrena	leaves	10 0ab*	26 4h	30 2i	9.2a	12 2e	20 7f	10 3bc	11.2cd	19 9f	16 7a
Ara	leaves	10.0ab	23.4g	32 4j	10 4bc	12 4e	23 8g	10.6bcd	11 6de	20 6f	17.2b
Means for P in leaves		22 1c			14 8b			14.0a			
Means for Pb in leaves		10 1a	16 2b	24 6c							

* Values followed by the same letter do not differ significantly

Earlier investigations conducted on reduction of lead uptake by plants from the substrate using phosphate salts gave ambiguous results. Bassuk (1986) stated that in loess soil with pH 6.8 containing 635 mg Pb · kg^{-1} d w a dose of 100 mg Pb · kg^{-1} d.w. will efficiently diminish lead accumulation in lettuce However, he also maintained that as a factor limiting lead uptake from the substrate, phosphorus is less useful than organic matter or other components with high cation-exchange capacity. Gorlach & Gambuś (1991) made similar observations A lack of any visible effect of phosphorus compounds on lead accumulation was usually detected at substrate fertilisation below 100 mg Pb kg^{-1} d w applied on heavier soils (Piesak 1988) A choice of phosphate salt was also extremely important as they differ both with their solubility and primarily with their reactions, which strongly determines their final effect

In practice it has been a well known fact that an excessive increase in soil phosphate contents may prove harmful due to limited microelement availability for plants. It is also known that solubility of phosphorous compounds decreases in soil revealing pH approximate to neutral, which is recommended for soils polluted with heavy metals. Thus the opinion that phosphates play a lesser role in limiting lead uptake in plants than typically structural components, like organic matter or clayey components, seems justified They cannot be introduced into the soil in unlimited amounts because of ecological security and relatively high costs Phosphate treatment should be treated rather as a supplementary measure considering key role of phosphates in plant resistance to heavy metals A decreased Pb translocation from carrot roots to leaves with increasing P content in substrate has been confirmed by the present experiment results. Similar observations were also made for corn (Zimdahl & Foster 1976) and radish (Gawęda 1996)

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WPŁYW ZAWARTOŚCI FOSFORU W PODŁOŻU NA KUMULACJĘ OŁOWIU PRZEZ MARCHEW (*DAUCUS CAROTA* L.) I SAŁATĘ (*LACTUCA SATIVA* L. VAR. *CAPITATA* L.)

Streszczenie

Przeprowadzono doświadczenie wazonowe w celu zbadania wpływu nawożenia fosforowego na kumulację ołowiu przez marchew i sałatę. Stwierdzono, że podniesienie zawartości fosforu w podłożu z 50 do 800 mg kg^{-1} s.m. spowodowało spadek zawartości Pb w korzeniach marchwi średnio o 44%, a w liściach sałaty średnio o 33%.